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(दूसरा पुनरीक्षण)

Industrial Plant Layout — Code of Safe Practice

(Second Revision)

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FOREWORD

This Indian Standard (Second Revision)was adopted by the Bureau of Indian Standards, after the draft finalized by the Occupational Safety and Health Sectional Committee, had been approved by the Chemical Division Council.

This standard was originally published in 1976. In view of the experiences gained over the period of about three decades, the standard was revised in 2008 to widen its scope to accommodate the outside facilities for which there was a separate standard IS 8089 : 1976 'Code of safe practice for layout of outside facilities in an industrial plant'.

The standard now revised to elaborate safe practices for 'Location of Building and Structures', 'Railway Sidings', 'Roads and Footpaths'.

There is no ISO standard on this subject. In the formulation of this standard, assistance has been derived from the following publications:

a) Accident Prevention Manual for Industrial Operations, 1969. Ed.6 National Safety Council, Chicago, USA
b) Loss Prevention in the Process Industries-Frank P Lees, 2nd edition

Indian Standard

INDUSTRIAL PLANT LAYOUT — CODE OF SAFE PRACTICE

(Second Revision)

1 SCOPE

This standard provides safe practices for layout and building structures inside as well as outside facilities in an industrial plant.

2 REFERENCE

The standard listed below contains provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the edition indicated was valid. All standards are subject to revisions, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the Indian standards.

IS No.	*Title*
2825 : 1969	Code for unfired pressure vessels

3 INTRODUCTION

3.1 Design for Safety

Plant layout is concerned with the spatial arrangement of processing equipment, storage vessels, their interconnecting pipe work, workplace and warehouse. This is an important aspect in the design of chemical and process plants, since a good layout will ensure that the plant functions correctly, safely and efficiently. It considers the design constraints arising from safety, environment, construction, maintenance and operation with an economical balance.

Access to the plant and supply of maintenance, construction and emergency services are all affected by the plant layout. Numerous accidents, occupational diseases, explosions and fires are preventable if suitable measures and code of standards are taken into considerations right from the earliest planning, design, and the initial project stage.

3.1.1 Efficiency and safety in industrial operations can be greatly increased by careful planning of the location, design, and layout (of a new plant or of an existing one) in which major alternations are to be made.

3.1.2 Plant layout will be based on following factors like:

a) New site development or addition to previously developed site,
b) Type and quantity of products to be produced,
c) Possible future expansion,
d) Operational convenience and accessibility,
e) Type of process and product control,
f) Economic distribution of utilities and services,
g) Type of building and building code requirements,
h) Guidelines related to health and safety,
j) Waste-disposable problems,
k) Space available and space requirement,
m) Auxiliary equipment, and
n) Roads and railroad.

3.1.3 The guidelines related to safety, health, welfare and provisions related to hazardous processes can be incorporated in the plant layout and have a statutory binding on the industry.

3.2 Building, Equipment and Processes

3.2.1 Major factors determining the size, shape and type of buildings and structures are the nature of the processes and materials, maintenance, mechanical handling equipment, requirement for gravity flow, equipment needing specially strong foundations; access for construction; commissioning, operation; space for future expansion, escape and fire fighting, containment of accidents; environmental impact and working conditions. These can vary greatly.

3.2.2 Catastrophes resulting in large loss of life and heavy property damage are often due to inadequate planning-stage consideration of the physical and chemical properties of dangerous substances and their processing methods. Hence, Code of practice should be strictly followed. Zoning/Division criteria should be considered at the planning stage. Hazard and Operability (HAZOP) and risk assessment should be undertaken. After this analysis, the best possible layout will emerge with major emphasis on safety.

3.2.3 High hazard processes should be located in small isolated buildings of limited occupancy or in areas cut off by fire-resistant materials appropriate to the hazard involved. Buildings can be designed so that internal explosions will produce minimum damage and minimum broken glass. Lower hazard operations can justify larger units. Chemical compatibility should be thoroughly reviewed for defining the storage, handling and use of chemicals in process.

3.2.4 Even less serious injuries resulting from poor housekeeping facilities and congestion of work places can be reduced substantially by preplanning for safety. Layout of equipment and buildings shall be such that production lines do not cross and that operators have enough working space. This saves time, increases production and helps prevent accidents. Pipe rack layout should also consider extra space to accommodate future modified lines and approaching space between overhead lines for ease of access during attending leaks, etc. Relevant safety standards and applicable regulations should be strictly followed especially for staircases in building, crane gang ways, railing and fencing such as those provided in *Factories Act*, 1948 and National Building Code 2016. Spatial arrangement of processing equipment, storage vessels and their interconnecting pipelines should be given utmost importance.

3.2.5 Personnel facilities such as lunchrooms and health services and disaster services are essential for reasons of health and treatment of injuries. They can be planned and located for maximum effectiveness. As far as possible fire station and medical facility like ambulance should be located adjacent to each other so that in case of emergency call, both the fire tender and ambulance will rush together to the emergency spot. Communication facilities should be adequately provided.

4 SITE PLANNING

4.1 Safety is a prime consideration in plant siting. Selection of a site involves consideration of a number of factors such as possible hazards to the community and their relationships to climate and terrain, space requirements, type and size of buildings, necessary facilities, availability of raw material, cooling water, transportation, market, labour supply, population density near the site and means of effluent disposal. Ground water survey can be undertaken to ensure the availability of water for industrial requirement. Of the factors listed, those of direct concern to the safety professional are given below. While the safety professional is not directly responsible for specialized plant and process engineering and design, still it is his duty to keep the engineers and architects as safety conscious as possible and to anticipate potential safety hazards and try to have them designed out of the system before the construction stage begins.

4.2 Location, Climate and Terrain

4.2.1 *Location*

As far as safety of the public is concerned, the most important feature is the distance between the site and built-up areas. Sites range from rural to urban, with population densities varying from virtually zero to high. Separation between a hazard and the public is beneficial in mitigating the effects of a major accident. An area of low population density around the site will help reduce causalities. Plants producing or using highly flammable or toxic substances in bulk should be located so as not to cause damage to a city or town, either generally or in case of disaster or some unexpected happening.

4.2.2 *Climate*

Study of the climate of the area may be required. It may reveal that, if a certain site is selected, the prevailing winds will cause noxious fumes or dusts to settle on a neighbouring community or plant, thereby doing severe harm to people or property or creating a nuisance. The prevailing winds may also determine the best location for processing equipment in relation to administration offices; especially their air conditioning air intakes; drainage and waste disposal problems shall also be anticipated. Winter conditions or winterization should be considered to protect the plant against severe winter conditions. The behaviour of airborne emissions of all types should be carefully considered. Although the predominant upwind direction is the main factor, other possible troublesome wind conditions should be taken into account referring to the wind-rose charts for past years. The effect of weather conditions such as inversions should also be considered. Location of air intake towers for air separation units should take into account, the wind directions, flare header locations (as hydrocarbon emissions from flare stacks can be sucked into the process causing severe accidents), and also the cooling tower locations to avoid corrosion of equipment and reduce moisture ingress into the compressors, etc.

4.2.3 In a hurricane, flood or seismic prone area, plans and specifications should include suitable protective measures and safety factors shall be designed into the operation.

NOTE — National Building Code 2016 give data on climatic changes and seismic zones with factor of safety to be taken while designing the building and equipment foundations.

4.2.4 *Terrain*

If site plans call for bridges over streams, ditches, and other hazards, be sure they are adequately protected by industrial fence or by hand rails 1 m high and intermediate rails. A typical layout is given in Fig. 1.

4.3 Space Requirements

4.3.1 Size of a site is determined by both present space requirements and possible future expansion. In the past the growth of business and population have resulted in serious crowding and the resulting congestion of buildings and other facilities has increased fire, accident and health hazards.

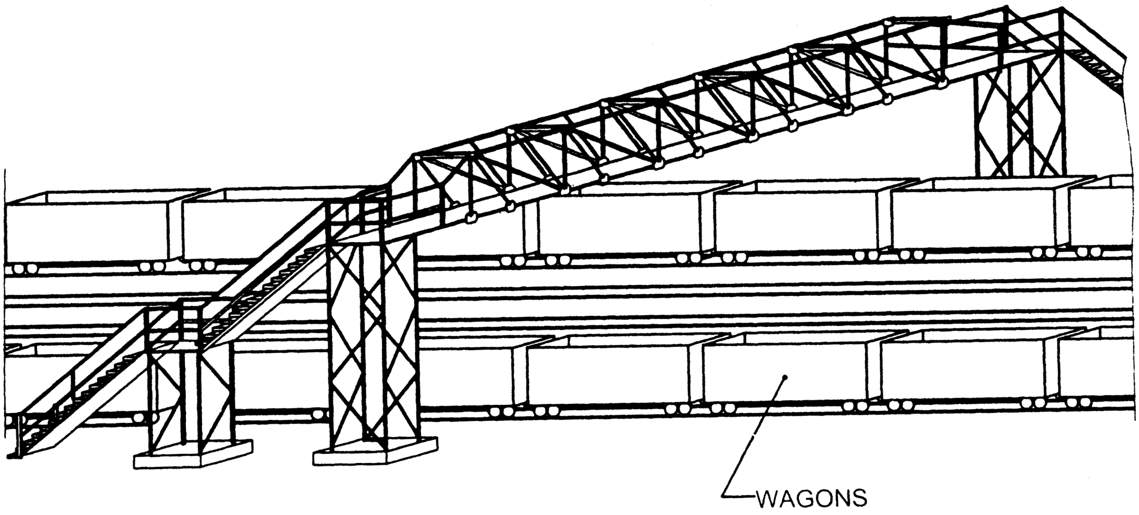


FIG. 1 TYPICAL LAYOUT OF A BRIDGE

4.3.2 *Site Services*

The site central services such as the boiler house, power station, switch station, pumping stations, utilities station, etc should be placed in suitable locations. They should not be put out of action by events as fire or flood and if possible not by other accidents such as explosion and that they should not constitute sources of ignition for flame. For example, factors in siting the boiler house are that it should not constitute a source of ignition and the emissions from stack should not give rise to nuisance.

4.3.3 New developments may figure in the size of the plant site. Some companies anticipating increased use of air transportation are allowing space for landing fields or heliports as they acquire new property. Plans for such installations should include all necessary safety precautions.

4.3.4 Fire prevention codes specify minimum distance between buildings according to their size, type and occupancy. Laws governing storage of explosives and of highly flammable materials specify minimum distances between manufacturing and storage facilities for various quantities of such materials, as well as minimum distance between the above from adjoining property.

4.3.5 Ample space for outdoor storage areas is essential. When the area for storing such materials as steel, pipe, and timber adjacent to shops proves insufficient, space has to be provided elsewhere. This necessitates added handling and transportation and increases both cost and accident risk.

4.3.6 Parking lots are best located inside the plant fence for convenience, protection, and safety. Since a considerable area may be necessary to accommodate employee and visitor cars, space requirements are important in site planning.

4.3.7 The site layout must accommodate the systems for handling the liquid effluents, gaseous emissions, solid wastes, storm water and firewater. For liquid effluents, one arrangement is to have three separate systems an open sewer system for clean storm water and two closed sewer systems, one for domestic sewage and one for aqueous effluent from the plant and for contaminated storm water, Process effluents are collected in a common sewer and closely controlled. The traditional sewer is the gravity flow type. This should have gradient and be self-cleaning. Measures should be taken to avoid flooding on process and storage plots. Drains should be designed to handle the corrosive materials and mixtures of materials, which may be discharged into them. In some cases, well-located disposal area for solid waste shall also be provided when a site is being laid out. Separate bins for paper, wood and metal be provided inside the premises, adjacent to road, in hazard free zone, for ease of lifting the material into a vehicle.

Gaseous emissions should be burned or discharged from a tall stack so that fumes does not affect the site or the public. A flare stack may have to be located to a distant site, because flare stack radiate intense heat, light, and can be very noisy.

4.3.8 Scale relief models of the site in addition to maps can be of much help to the planner in predesign and will help in spotting potential safety problems.

5 PLANT LAYOUT

5.1 General

5.1.1 Size, shape, location, construction and layout of buildings and other facilities should permit the most efficient utilization of materials, processes and methods.

5.1.2 Some materials and processes may favour gravity flow and the construction of a multistorey building, for example, in the case of mills for one treatment. In processes, where material charging is to be done through trolleys or drums, which are required to be carried from one floor to other, elevators may be provided, to avoid accidents in lifting them.

5.1.3 Other uses, such as automobile assembly plants may favour a one-storey building because floor loads will be heavy and excessive handling of materials by vertical and inclined conveyors would be required in a multi-storey building.

5.2 Location of Buildings and Structures

5.2.1 The segregation of raw materials storage, processing buildings and storage for finished products warrants thorough study in laying out a plant to minimize fire and explosion hazards. Storage of volatile flammable liquids in an area apart from processing buildings reduces the fire hazards. In the event of fire, control is more easily achieved. Moreover, the coast of separate storage eventually may be less than the investment for storage in a processing building. The site should aim to contain an accident at source to prevent escalation and avoid creating hazard to vulnerable targets.

Analytical laboratories should be in a safe area but otherwise as close as possible to the plants served. So should workshops and general stores. The stores also required ready access for stores materials.

5.2.2 Ample space should be provide between segregated units, from such flame sources as boilers, and from shops, streets and adjoining property. The codes of local, state and central authorities should be followed in planning the location of the units of a plant.

5.2.3 Wherever storage of explosives is involved, magazines should be located and constructed in accordance with the recommendations of the Department of Explosives.

5.2.4 The type of retardant required in relation to the horizontal distance between building of frame, brick and fire-resistant construction and minimum separation distances between buildings shall be as required by government regulations.

5.2.5 Many plants use and store flammable liquids having flash points below 93°C. Plans and layouts in such plants should conform strictly to specifications for handling and storing flammable liquids stipulated by Petroleum and Explosives Safety Organization (PESO) of Government of India.

In large petrochemicals complex/refineries, multi fire station locations for a minimum distance from all plants should be considered. Containment infrastructure should be provided for leakage in underground storage tanks.

Statutory specifications shall be met in storing flammable liquids outside the buildings in underground or above ground tanks. The amount of liquid that can be stored in an underground tank depends upon the proximity of the tank to any building, depth in the ground in relation to the building, and flash point of the liquid. Standards for tanks include type and thickness of material, provisions for relieving excessive internal pressure, grounding, insulation, piping, and other appurtenances, and similar details (*see* IS 2825).

5.2.6 The required distance between the line of adjoining property, which may be built upon and the location of an aboveground tank depends upon the content, construction, fire extinguishing equipment and greatest dimension (diameter or height) of the tank. Consequence risk study should be carried out to determine safe distances of building from flammable storage tanks.

5.2.7 Tanks shall be built of steel unless the properties of the flammable or combustible liquid are such that some other material has to be used for its corrosion resistance.

5.2.8 The distance between occupied buildings and plant buildings will be governed by the need to reduce the dangers of explosion, fire and toxicity. In particular, evacuation routes should not be blocked by poor plant layout. Administration buildings should be situated in safe area on the public side of the security point. The main office block should always be near the main entrance and other administration buildings should be nears this entrance, if possible. Other buildings such as medical centers, canteens, etc, should be in a safe area and the latter should have ready access for food supplies. Consideration should be given to siting of occupied buildings outside the main fence. In all cases occupied buildings should be sited predominant upwind of hazardous plant areas.

5.2.9 *Control Facilities*

The control building should protect its occupants against the hazards of fire, explosion and toxic release. The control building should be situated on the edge of the plant to allow an escape route. Recommended minimum distances between the plant and the control building tend to lie in the range 20-30 m. Depending upon hazard studies, distance between the control room building should be increased. It should not be so near the plant that its occupants are at once put at risk by serious leak of flammable, toxic or corrosive materials. The control building should contain only the essential process control functions only one storey above ground. The building should be oriented to present minimum area to probable centers of explosion, with a strong construction, constructed in ductile materials (Ductile material include steel and reinforced concrete).

The control room should not be used as a center to control emergencies, nor it should be used as an emergency assembly point. There should be a separate emergency control centre for controlling the incident by the incident controller, having necessary arrangements for positive pressure inside.

5.2.10 Water drift from cooling towers can cause corrosion of plants, air intake towers, increase vibration in centrifugal air compressors, so the towers should be sited to minimize this. The entrainment of effluents from stack and of corrosive vapors from plants into cooling towers or air separation units should be avoided should the siting of buildings near the tower intakes. The positioning of natural draught cooling towers should also take into account resonance caused by wind between the towers. Another problem is recycling of air from the discharge of one tower to the suction of another, which is countered by placing towers cross-wise to the prevailing wind. Further guidance is available in standard references.

5.2.11 *Escape*

A minimum of two escape routes should be provided for any workspace, except where the fire risk is very small. No workplace should be more than 12-45 m, depending on degree of risk, from an exit, and a dead end should not exceed 8 m.

Escape routes across open mesh areas should have solid flooring. Escape stairways should be in straight flights preferably be on the outside of buildings. Fixed ladders may be used for escape from structures if the number of people does not exceed 10. Escape routes should be at least 0.7 m and preferably 1.2 m wide to allow the passage of 40 persons/min on the flat and 20 persons/min down stairways. The escape times of personnel should be estimated, paying particular attention to people on tall items such as distillation columns or cranes.

The main switchgear and emergency controls should have good access, preferably on an escape route, so that the operator does not have to risk his life to effect shutdown.

Emergency lights to be provided in high occupancy area, escape pathways and exits.

5.2.12 *Fire-Fighting*

Access is essential for fire-fighting. This is provided by the suggested plot size of 100m×200m with approaches preferably on all four sides and by spacing between plots and buildings of 15 m. Some basic principles are that it should be possible to get fire-fighting equipment sufficiently close to the site of the fire.

Hydrant points should be positioned so that hoses can reach any fire on the plot. Hydrant spacing of 48, 65 and 95 m are suitable for high, medium, and low risk plots, respectively. Plants over 18 m high should be provided with dry riser mains and those over 60 m high or of high risk should be equipped with wet riser mains. The inlets on the ground floor to dry riser mains and the outlets on all floors to both types of main should be accessible. Fire equipment should be located so that it is not likely to be disabled by the accident itself. The site layout should contribute to the containment of any fire, which may occur, and to combating the fire. Feature of the site layout relevant to fire hazards are illustrated in the Fig. 2 and Fig. 3 and described in Annex A.

5.2.13 Compressors should be located in different buildings with acoustic enclosure to reduce noise.

5.3 Flow Sheet

5.3.1 A detailed flow sheet is a useful guide in the layout of plant, particularly those using dangerous and harmful materials and complicated processes. The nature of the materials and processes in each manufacturing stage can be studied and provision made to eliminate or control hazards. A typical flow sheet and layout showing a hazardous operation is given in Fig. 4.

5.3.2 A comprehensive risk assessment study can be done which is based on consequence analysis and engineering judgment can lead to a set of conclusion and risk mitigation to arrive at a safe process flowsheet (HAZOP). Computer aided design (CAD) application can be used to plan the layout and flow sheet.

5.4 Layout of Equipment

5.4.1 Various methods are used to determine the safest and most efficient layout of production machines and equipment. The two-dimensional method consists of templates made to scale and fitted into a plan of the site or floor area.

Now a days, computer aided design (CAD) methods are widely used. One type of Code gives visualization of the layout, 2D or in 3D forms. Typically such CAD packages not only give 3D display, but hold a large amount of information about the plant such as coordinates of the main items and branches, the piping routes, the materials list etc.

5.4.2 The most effective method is to use three-dimensional models, made to scale and set up a scaled floor plan. The models can be rearranged until the safest and most efficient layout has been devised.

5.4.3 Layout studies show the most suitable locations

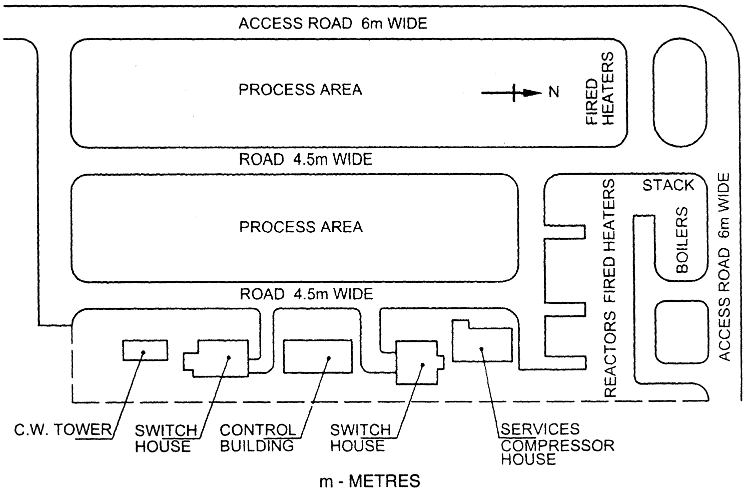


FIG. 2 COMPACT BLOCK LAYOUT SYSTEM IN THE PROCESS AREA OF A PETROCHEMICAL PLANT WITH 4.5 m METRE ROADS

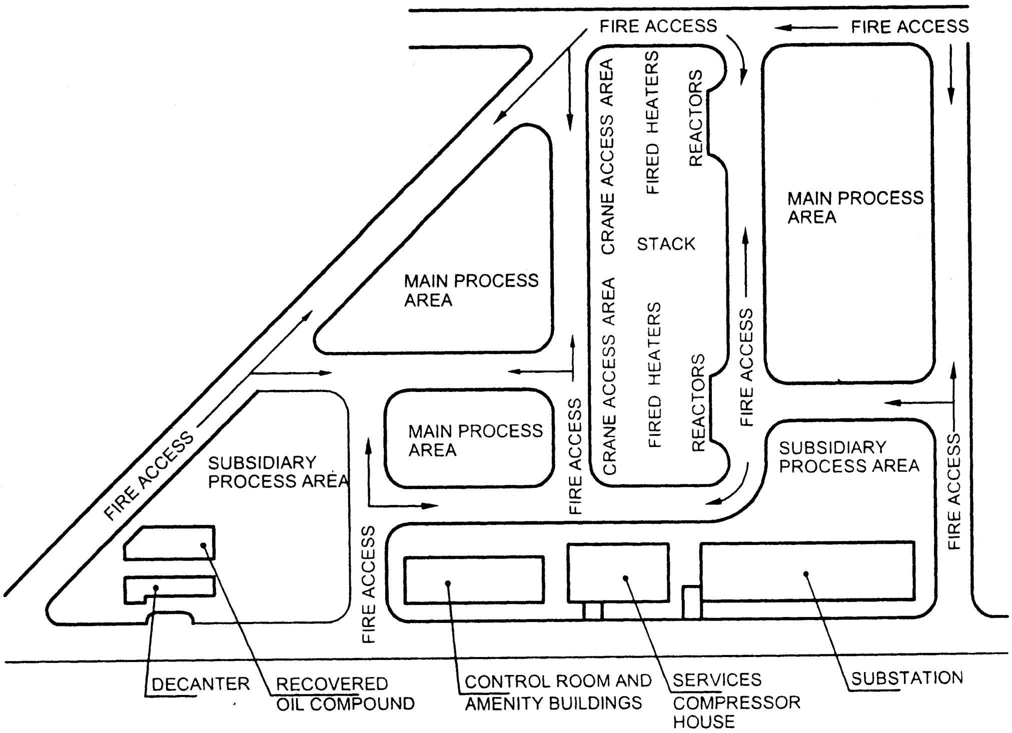


FIG. 3 BLOCK LAOUT SYSTEM IN THE PROCESS AREA OF A PETROCHEMICAL PANT WITH 6 m ROADS

for spray-painting, welding and similar work generally requiring segregation as they related to other operations.

NOTE — Results to be obtained through layout studies are shown in Annex B.

5.4.4 By using the three-dimensional method (3D) model of the space occupied by each item of equipment, congested areas can be anticipated and avoided. These pile-up areas mean frequent handling of materials, many unnecessary movements, and result in bad housekeeping, which, may be in itself a prolific source of accidents. This 3D envelope should include space for,

a) operations access,
b) maintenance access, and
c) piping connections.

Preparing a scale model showing details of the plant layout will help in determining the best location for equipments and facilities. It will also easily locate errors in a plant layout.

5.4.5 Insufficient headroom at aisles, platforms,

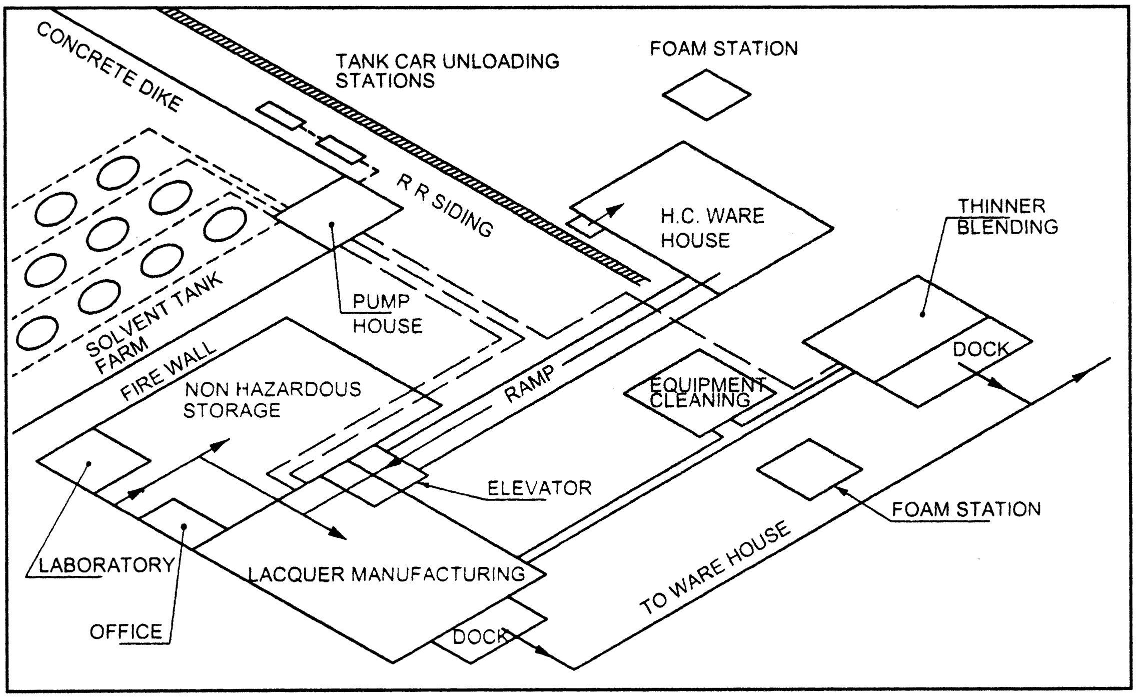


FIG. 4 COMBINATION FLOW SHEET AND LAYOUT SHOWING A PLANT HAVING HAZARDOUS OPERATIONS

pipelines, overhead conveyors, other parts of the structure and other installations is disclosed in studying the models. A vertical distance of at least 2.2 m is generally specified between passage stairways and overhead structures to provide ample clearance. Overhead cranes and conveyors require at least 60 cm of vertical and horizontal clearance.

Walkways along overhead cranes and conveyors should be provided for safe inspection and maintenance.

5.4.6 Trucks and other vehicles require enough room for movement without endangering men and equipment and need space to back and turn near machines. Aisles should be wide enough to permit trucks to pass without colliding. For one-way traffic, aisles should be not less than 1 m wider than the widest vehicles. Aisles for two-way traffic should be not less than 1 m wider than twice the width of the widest vehicle. These minimum widths are exceeded considerably in some new buildings where, because of anticipated heavy traffic, aisles from 4 to 6 m wide have been specified. Considerations to be taken into account of bigger capacity tankers, before constructing loading bays and gates. Adequate radius should be provided near the loading bay for easy movements of the tankers. Separate routes must be made for tanker movements inside the tank farm (not from inside the plant roads).

5.4.7 Safe layout of aisles requires that there should be no blind corners and that adequate radius be provided to allow for vehicle turns. A 2 m radius is large enough for small industrial trucks.

5.4.8 Aisles should be clearly defined with approved markings of either traffic paint or striping material. Plastic buttons that are glued or fastened with metal fasteners to the floor, are used by many because of their durability. Aisles should also be clearly identified around every machine in a workshop with minimum 1 m clearance maintained for easy movement of personnel considered.

5.4.9 Parking areas for both hand and power trucks should be designated. Large plants often provide garages with room for both storage and maintenance.

5.4.10 If building plans include ramps for use by pedestrians and trucks, a 1m wide section should be reserved as a walkway, and it should be clearly defined with approved markings of traffic paint. Sharp turns into aisles at the top and bottom of ramps are hazardous and should be avoided. Provide an abrasive coating where slippery-floor conditions may exist.

5.4.11 If the process materials are corrosive, this aspect should be taken into account in the plant layout. Foundations of both the buildings and machines, especially those constructed in concrete, may be attacked by leakage of corrosive materials. Additional thickness of concrete and corrosion resistant asphalt, bricks, and plastics can be used. Floors should be sloped so that spillages are drained away from vulnerable equipment, walkways and traffic lanes. Pipe flanges, which may drip corrosive substances, should not be located over walkways.

5.4.12 Operators cabins must be located inside the plant in low hazard, low noise area for better communication and coordination in daily activities and during emergencies.

5.5 Electrical Equipment

5.5.1 Electrical substations should be located in areas where non-flameproof equipment can be used, except where they are an integral part of the plant. Complete metal enclosed unit substations have been developed for industrial plants and are grounded. Such rooms, however, are not proof against the hazards of oil-filled transformers. This equipment may give off flammable vapours under certain conditions, which may form an explosive mixture with the atmosphere in the room. Non-flammable transformers should be installed with the atmosphere in the room. Non-flammable transformers should be installed in confined areas and near flammable materials. Transformers should be separately located outside the substation building. Substation of individual plant should be located nearer to the control room for better coordination between the process and electrical department and also for ease in early detection of any untoward incidents like fire.

High voltage and low voltage Motor Control Center, MCC's panels should be clearly demarcated and all MCC's should be easily identified by numbering and with list of motor drives under them.

In case of any electromagnetic waves emitted from cellular phones/walkie-talkie affects particular MCC, it should be located in a separate room with a caution board.

5.5.2 Short-circuit protective devices should be large enough to carry the load and should be rated to open without any danger from the maximum short-circuit current. Circuit breakers, fuses and safety switches that fail under short-circuit current may explode and cause serious damage and injuries.

5.5.3 The potential of every grounding system should be measured with a meter to determine whether or not the system is capable of conducting the necessary amount of return.

5.5.4 When direct current voltage is supplied from batteries, isolate the battery room from the work area. Battery room should be well ventilated and no smoking should be permitted.

5.5.5 In an up-to-date industrial electrical system, sections may be de-energized for maintenance and other work without shutting down the entire system. In addition, all electrical installations should conform to the local regulations. Lighting protection should be designed to ensure that all storages and building are adequately secured.

5.5.6 Major switching apparatus should have metal enclosures connected to the grounding system and cable circuits likewise should be enclosed in rigid conduit or interlocked armor cable. Metal enclosed plug-in-bus-ways should provide an easy method of connecting and disconnecting machine tools.

5.5.7 Ungrounded portable electric tools and equipment constitute a common source of fatalities in industry. The hazard can be largely eliminated if plans include a three-wire system of which one is a ground wire and if the equipment is provided with three conductor cables. Eath Leakage Circuit Breaker (ELCB) provision should be made to avoid shock from leakage current.

5.6 Ventilation, Heating and Air Conditioning

5.6.1 Ventilation, heating and air conditioning are needed for both for personal comfort and very often to meet process conditions. Personal comfort is very important because it affects employee efficiency. All efforts should be made not only to make general office and plant conditions comfortable but also to eliminate or at least reduce poor conditions which can contribute to excessive employee fatigue or discomfort. If machinery or processes radiate heat or generate bad fumes, extra ventilation should be supplied to the work area. Where the ventilation rate is set by the need to remove a contaminant, the number of air changes per unit time is an appropriate measure.

5.6.2 Boilers, fans, and air-conditioning equipment are usually kept separate from the general work areas because their adjustment is very fine. It is important to make certain that boilers receive adequate air and that combustion by-products are exhausted safely. In locating incinerators too, be sure that a negative pressure differential in a building does not cause an incinerator stack to serve as an air source.

5.6.3 Maintenance should be considered. Not only shall authorized employees have easy access to the machinery, but also there shall be sufficient space around the equipment to replace parts as needed. There shall be room behind to pull the tubes if necessary.

5.6.4 The control room and other work place should be maintained at positive air pressure to avoid ingress of dust and fumes from outside and also to dissipate panel heat.

5.7 Inside Storage

5.7.1 Industrial buildings seldom have enough storage room. Sufficient space for raw materials and finished products may be estimated on the basis of maximum production requirements with allowances for shortages, seasonal shipping and quantity purchases.

5.7.2 Modern mechanical handling and stacking equipment permits extensive use of vertical space through double and triple decking. If this method is anticipated in the future, basic live floor requirements in the initial building design shall allow for the possible increase in m^2 load. Systematic optimization based approach and certain available software packages can be used for increasing space efficiency.

5.7.3 Plans for storage of supplies, the finished product and empty or full pallets should permit ease of access, stability of piling or stacking and proper functioning of the emergency sprinkler system. Sprinkler design density ($l/min/m^2$) and area of application are dependent on type of material and the height to which it is piled. When piling height exceeds 3.5 m, double-check the sprinkler system's ability to put out any fire.

Space for storing supplies, tools and in frequently used equipment near working areas is seldom included in plans for departmental layouts. The result is that such items often are left in unsafe positions and locations. To discourage employees from leaving long materials and parts against walls or other places where they can fall, potable ladders, tools, such as pry bars and machine parts such as shafts should have definite storage places.

5.7.4 Space should be provided for racks, bins and shelves. Materials that project from such places should be stored above eye level and barricaded. Metal baskets or special racks provided with drip pans can be used for storing machine parts covered with cutting oils. Flooring in oil storage area should be made antiskid and impervious.

5.7.5 Closets should be built for the storage of sanitary supplies such as deodorants and soaps.

5.7.6 Waste storage may take considerable room, especially if the waste is bulky or is produced in large quantities. In buildings with basements, chutes to basement storage bins help prevent accumulations in working areas. To dispose of small quantities of sharp-edged waste, boxes with handles that are protected from contact with sharp materials or similar safe containers may be specified.

5.8 Receiving and Dispatching

5.8.1 Receiving and dispatching facilities should fit in with overall material flow within the company or plant and should aid efficient flow of materials into and out of production areas. Separate material gate should be provided, like liquid movement, solid logistic movement, etc. that shall ensure all entries related to excise and taxation. Receiving and dispatching areas should be designed to keep building heating and cooling losses at a minimum.

5.8.2 Self-leveling dock boards, truck levelers, and cranes can facilitate loading and unloading. Stores/Load office should be near to the material gate to have inward receipt of the goods.

5.8.3 Separate truck siding should be provided near the material gate for parking of trucks after their movement of loading of finished goods or raw materials unloading. Parking facility should also be provided for tankers, which are in queue for loading/unloading. In such case, proper communication (like pubic address system, walky-talky, hot lines, etc) between parking facility and the load office should be provided with security posts to control the vehicular movement. Facilities of toilets and canteen should be provided so as to avoid movement of Drivers in the work premises.

5.8.4 Dispatch of all finished goods should be done from a separate location in the factory without interfering the movement in work premises. Proper barricade with security gate should be made to avoid any unauthorized entry of vehicle in the plant premises.

5.9 Railway Sidings

5.9.1 This commonly used receiving and dispatching facility requires planning, especially if bulk receiving of raw, process and maintenance materials is an economic advantage. Tank wagons containing hazardous materials, such as chlorine, caustics, acids, and other volatile, flammable, explosive and toxic materials, require proper consideration for pressure piping, break away piping, valves, pumps, derails, etc.

5.9.2 Each side track should be guarded away from main line, public thoroughfares, and proper clearance between main plants and wagons observed.

Guidelines provided by the railways should be followed while making a layout for a railway siding, making provision for the following:

a) Gateways;
b) Barriers and turn gates;
c) Track clearances; and
d) Crossings, etc.

Worker's pay windows, first-aid stations and other points where a crowd may collect should not be placed near a railway track.

Reflective jackets and search lights (torch) should be provided to personnel working in night in siding. Adequate illumination and reflective markings should be applied at key pathways and work places.

5.10 Roads and Footpaths

5.10.1 The safety engineer should always be alert to opportunities where he can assist the civil engineer in designing for maximum safety. Roads in plant yards and grounds are sources of frequent accidents unless they are carefully laid out, substantially constructed and well surfaced and drained and kept in good condition.

5.10.2 Heavy duty motor truck hauling requires road tip to 16 m wide for two-way traffic with ample radii at curves. Gradients, in general, are limited to a maximum of 8 percent. A slight crown is necessary for drainage, with ditches to carry off water.

5.10.3 Road should be located at least 11 m from buildings, especially at entrances. At loading docks an allowance of one and a half truck length is desirable to facilitate backing.

5.10.4 Intersection of roads should provide clear sight distance taking into account width of the roads, traffic, sighting angle, etc.

Provisions of CCTV (Closed Circuit Tele-Vision) is recommended for better control and monitoring of all movements.

5.10.5 The regulation and control of traffic, signs, road layout, and markings should conform to local and state practices.

5.10.6 Traffic sings and signals regulating speed and movements at hazardous locations are essential. Stop signs are specified for railway crossings and entrances to main thoroughfares. 'STOP, LOOK AND GO' and 'SOUND YOUR HORN' signs are necessary at sharp curves (blind corners) where view is obstructed and at entrances to buildings. Mirrors mounted to afford views around sharp turn or corners of buildings are of great help in preventing accidents, if roads have to be built close to buildings. Barricades and 'MEN WORKING' signs are needed for construction and repair work. Speed limit boards and Speed breakers with appropriate indications shall be installed before entrance/exit of plants, sharp curves, blind corners and also before such places where speeding vehicles would pose a particular hazard to pedestrian traffic and/or other vehicles moving in the area. If roads are used at night, traffic signs should be made of reflective or luminous materials. Separate gates should be used for allowing shift buses employee's entrance/exist and other vehicles.

5.10.7 Good footpaths between outside facilities prevent injury from employees stepping on round stones or into holes and ruts on rough ground. As far as possible, footpaths should be the shortest distance from one building to another to discourage short cutting. A footpath that has to be next to railway tracks should be separated from them by a fence or railing. Warning signs should be installed at railway crossings and other hazardous places.

5.10.8 Concrete is preferred for footpaths, especially in principal areas like entrances and between main buildings. Crushed rock surfaced with gravel or asphalt makes a good footpath for less used locations. Also pedestrian's footpaths/railway can be made on both sides of main road clearly defined with approved markings of traffic paints.

5.10.9 Footpaths should be kept in good condition, especially where they cross railway tracks and should be cleared of ice and snow.

5.11 Parking Areas

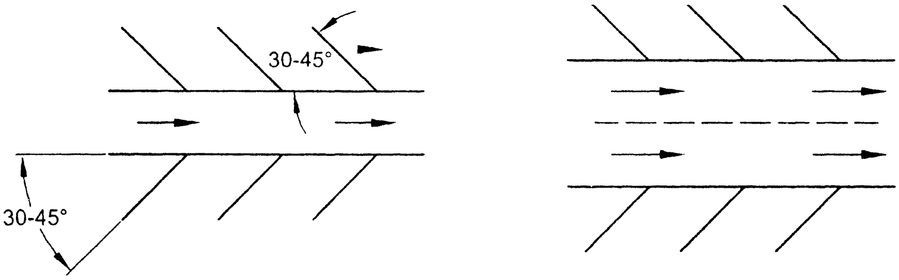
5.11.1 To reduce travel in the plant grounds, a desirable location for a parking area is between an entrance and the locker room. The entire parking area should be fenced. The parking stalls shall be laid out so that driving in, parking, opening of car doors and driving away is not obstructed. Typical layouts of parking stalls of staggered and non-staggered types are indicated in Fig. 5A and Fig. 5B respectively. The surface of the parking area should be smooth and hard, to eliminate the frequent injuries that would occur from falls on stony or rough ground. Good drainage is essential.

5.11.2 The use of white lines 10 to 15 cm wide to designate stalls reduces confusion and the number of backing accidents. Standard stalls are 5 m wide and 6 m long. The centre-to-centre distance between parked cars varies according to the method of parking. Be sure that parking does not encroach on approaches to comers, bus stops, loading zones and clearance spaces for islands. Driveways should be a minimum of 8 m for two-say traffic and there should be no obstructions to viewing.

5.11.3 Angle parking has both advantages and disadvantages. The smaller the angle, the fewer the number of cars that can be parked in the same area. Aisle widths can be narrower but traffic is usually restricted to one way. On the other hand, angle parking is easier for customers and it does not require a lot of room for sharp turns.

5.11.4 The area allowed per car in parking lots varies from 20 m^2 to more than 30 m^2, if aisles are included. Large and economically laid out areas may approach the 20 m^2 figure; smaller and poorly configured parking areas may have a higher percentage of aisle space and may approach 30 m^2 car. A large commercial attended parking area is considered efficient if the layout keeps the space requirements to 24 m^2 per car.

5.11.5 Separate entrances for incoming and outgoing cars facilities orderly traffic movements. Entrances should be designated with suitable signs. Speed signs and sings limiting areas to employees or visitors should be installed, as circumstances require. These signs



5A Staggered

5B Non-Staggered

NOTES

1 In both patterns, vehicles have to reverse into parking space.

2 For parking areas with restricted lane widths, a slope angle of 30° is suggested. Depending upon the adequacy of lane width any angle up to 45° is recommended.

FIG. 5 TYPICAL LAYOUTS OF PARKING STALLS

should conform to recommended standards and would be similar to other street and highway signs.

5.11.6 Traffic at exit to heavily travelled streets should either be controlled by a traffic light, or, there should be acceleration or merging lane.

5.11.7 If the area is used at night, adequate lighting should be provided for safety and for the prevention of theft, about 100 lux/m^2 at a height of 1 m should be an adequate level.

5.12 Additional Facilities

Consideration of following suitable additional facilities should also be borne in mind at the designing stage:

a) Greater use should be made of mechanical handling devices, such as conveyors, bucket elevators, etc, in order to reduce transport by rail and road to an optimum extent.
b) Sectionalizing arrangement should be made in electrical supply line to equipment.
c) Planning and erection of equipment should take into consideration facilities for repairs and preventive maintenance work.
d) Equipment layout/installation should also consider the case of removal of the equipment (by cranes), especially when located on higher floors.
e) As far as possible, bridging of the platforms of adjacent columns (distillation, scrubbers, evaporators, etc) should be done, for ease of operation especially during shutdown and start up.

ANNEX A

(*Clause* 5.2.12)

SITE LAYOUT RELEVANT TO FIRE HAZARD

A-1 Figure 2 shows a compact layout, which minimizes land usage and pipe work, for petrochemical plant consisting of a major process with several stages and a number of subsidiary processes.

There are two main process areas and at right angles to these is an area with a row of fired heaters and associated reactors, steam boilers and a stack.

This layout has several weaknesses. The lack of firebreaks in the main process blocks would allow a fire to propagate right along these, particularly if wind is blowing along them. There is entry to the plant area from the 6 m roads from opposite corners, which allows for all wind directions. But the only access for vehicles to the process plots is the 4.5 m roads. In the case of a major fire, appliances might well get trapped by an escalation of the fire. Clearance is also not adequate. The layout also likely to cause difficulties in maintenance work.

A-2 The alternative layout shown in Fig. 3 avoids these problems. The process areas are divided by firebreaks. There are more entry points on the site and dead ends are eliminated. The crane access areas provide additional clearances for fired heaters.

ANNEX B

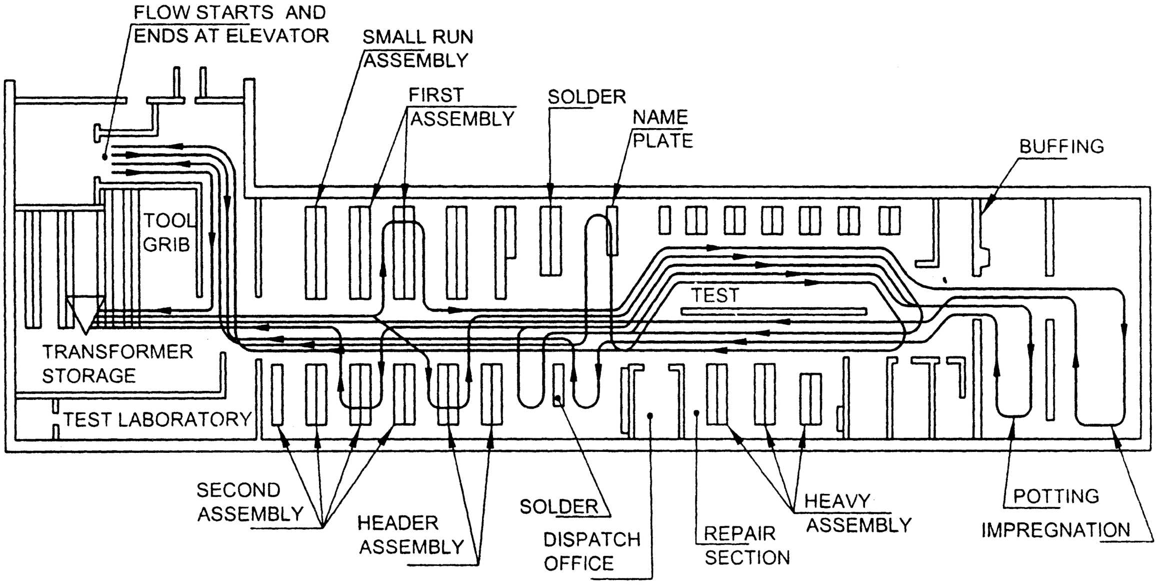
(*Clause* 5.4.3)

RESULTS OF LAYOUR STUDIES

B-1 Results to be obtained through layout studies are shown in Fig. 6.

B-2 Here the new layout reduced unit travel from 772 m to 246 m of which 63 m are conveyorized. The saving in distance amounted to about 76 percent. The reduction is particularly significant to the safety professional because the largest number of injuries in most industries occur in material handling.

OLD LAYOUT



PRODUCTION FLOW OF HERMETIC UNIT

NEW LAYOUT

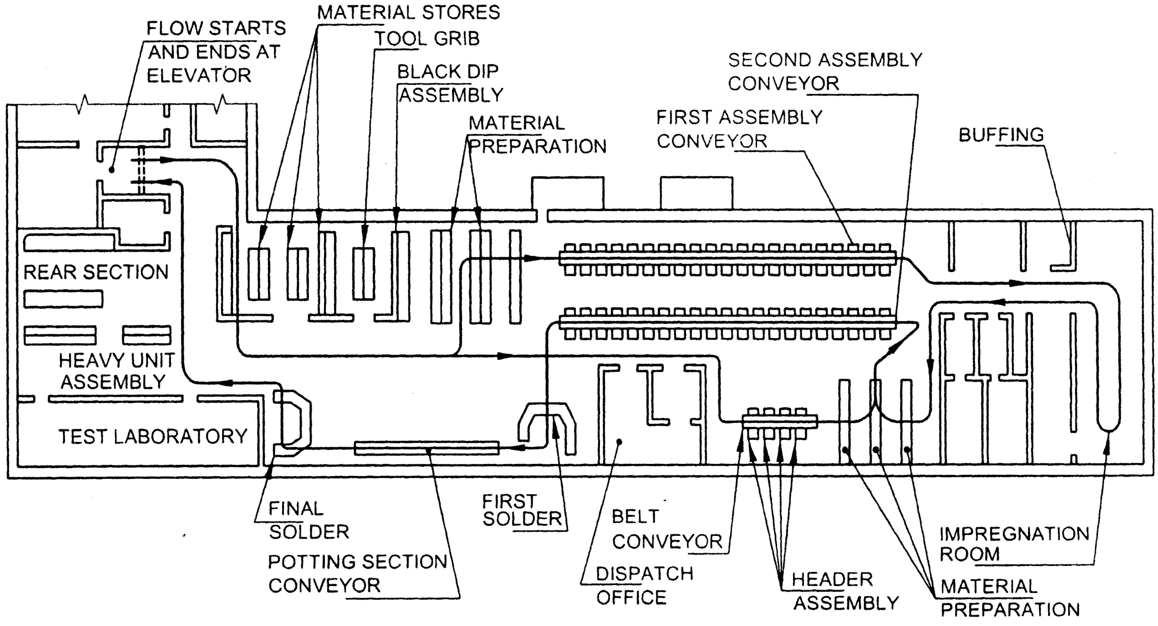


FIG. 6 THE OLD AND NEW LAYOUT OF TRANSFORMER MANUFACTURING OPERATION

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